NEW MACHINES SELECTION TOOLS USING ANALYTIC HIERARCHY PROCESS

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Abstract

This paper describes new machine tool selection process using the Analytic Hierarchy Process (AHP method) implemented in Expert Choice software. Machines selection is understood as serious investment. In situations like this companies have to make the best possible decision, because it has great effect on company's future. The AHP method is considered as a good way to make an appropriate decision in short time and in an easy way, using Expert Choice software. The advantages and disadvantages of using this method while choosing new machines are explored.

Keywords: decision support systems, analytic hierarchy process, machines selection tools

1. INTRODUCTION

New machines selection is a great investment for every company, no matter if the company is a small or a large one. That is why the decision should be right and accurate, as objective as possible so that it would not be a cause of unwanted loss in the future [1]. There are many ways to make a decision [2], one of them is the use of decision support systems [3]. The use of mathematical models for the evaluation of the criteria is expected. One of such methods is AHP (Analytic Hierarchy Process) [4], implemented in Expert Choice software [5]. Analytic Hierarchy Process is based on mathematical model which calculates evaluated criteria built by user and alternatives chosen also by user and in the end suggests goal - decision.

Is this really a good method to be used and in which cases is this method functional is the main theme this paper considers.

2. PRODUCTS AS THE REPRESENTATIVE PART OF THE RANGE

Since there is enormous number of machines on sale [6], some criteria should be made before the structure of AHP method is created. These criteria will enable decision making about adequate alternatives. The products for which the new machine will be selected are shown in Figure 1. These are aluminium alloy products having max. dimensions up to 100 mm. They require usual machining operations like turning, boring or milling.

Figure 1 – Representative products for manufacturing

The first criteria when it comes to alternative selection will be working space dimensions, which will be usually chosen by each producer to be the smallest available. Working space dimensions are usually connected with other machine features like power, travel or spindle characteristics.

To test the use of AHP method in situations like this, two cases will be considered. In the first one only five alternatives will be considered, while in the second one eighteen alternatives will be considered. Two scenarios are made because such situations are usual in real manufacturing. Sometimes a decision has to be made only between a few alternatives, but sometimes the process gets more complicated and many alternatives have to be considered.

Alternatives in the first case are (THE FIRST SCENARIO):

1. HAAS EC-400,
2. HAAS VF1,
3. HURCO VMX 10i,
4. HURCO VMX 24i,
5. HURCO HMX 500i.

In the second case the following machines are added (THE SECOND SCENARIO):

1. Heller H 2000,
2. Heller H4000,
3. Heller FP2000,
4. Heller FP4000,
5. Bridgeport XR 1000,
6. Bridgeport GX300,
7. Bridgeport GX510,
8. Bridgeport GX 480,
9. Bridgeport GX710,
10. HAAS VF-1YT,
11. Shengyang VMC850E,
12. Leadwell VL500L,
13. Mitseiki CV-1200A.

3. CONSIDERED CRITERIA IN DECISION SUPPORT/AHP METHOD

Criteria for the new machine tools selection are based on the brainstorming process of experts [7]. So far, this is the only way. They are structured in detail and shown in Figure 2.

Figure 2 – Machine tools selection criteria

It can be seen from Figure 2 that these criteria include technological, financial, ergonomic, ecological and criteria regarding interaction with the manufacturer. Rating of the criteria depends on the person that makes the decision [8]. In this case, the most important (influential) are auxiliary time, financial criteria, technological criteria, technological parameters and manufacturing cost. There is no objective way to show or prove that criteria are well structured or that all of the needed criteria are included. This is one of the disadvantages of this process – major influence of human factor [9]. The structure and criteria type depend exclusively on the person who makes the decision. The only way to improve them is by team work and by including as many experts as possible so they can give their opinion about this case [10]. However, it should be also noted that too many people involved in the process can be contra-productive, so an effective balance should be made.

4. EVALUATED RESULTS – FIVE ALTERNATIVES AS THE RESULT OF THE FIRST SCENARIO

When it comes to smaller amount of alternatives, model structuring in Expert Choice software is pretty easy, which provides the possibility to create difficult criteria structure. Alternatives can be easily compared concerning both the quantitative and qualitative criteria. Especially when it comes to qualitative criteria, it is possible to get more accurate comparison and final results. In the considered case, the quantitative criteria are based on technical data provided by the sales or production company. When it comes to qualitative criteria, like for instance, ecological or ergonomic criteria, the only way to compare the machines is by their size or power. Generally speaking, specialist knowledge is required. But with lack of quantitative data, previously mentioned alternatives must be evaluated as qualitative criteria. It is assumed, for example, that bigger machines are more difficult to recycle.

Two cases were made – the first one for small series production and the second one for big series production. Regarding the difference in mass and single production, to be more correct, different parameters and effects a bigger series has compared to the small one, it is expected that the results may vary. In both cases the first choices were the same (Figure 3 and Figure 4). Overall inconsistency in both cases is 0.04, which is less than 0.1 required limit given by Saaty and used in practice. This means that the model is acceptable and it can be used in further evaluation [4].

It can be seen from Figures 3 and 4 that Hurco HMX 500i is the first choice in both cases, since it has the best performances. But there is a difference in other choices – when it comes to the big series production, HAAS VF1 is the second choice, while Hurco VMX 10i is better in the small series production. This leads to the conclusion that the "size of series" criteria are very influential and can change the final result. The influence of criteria can be seen in Figure 5, presented for the big series production. With the bigger size of the series some influence of certain technical criteria changes, preparatory time increases, required machine power is more important (more powerful machines are needed), also the automation level and the number of pallets are more influential factors. Cost by hour decreases as well as amortization criteria.

In Figure 5 on the left the criteria and their influences are given. The graph on the left shows that most influential criteria are auxiliary time criteria, followed by the financial criteria. On the right the alternatives and the contribution of each criterion in the final result are given. It can be seen that Hurco HMX 500i is the best, concerning the auxiliary time, which is the most important criteria, so this is the reason why it is the first choice in this model. On the other hand, this machine is the worst choice when it comes to the second most influential criteria – financial criteria. In this case, Hurco VMX10i is the best choice. This leads to the benefit/cost calculation. Thus, HAAS VF1 is the first choice, which is, in the end, a logical result.

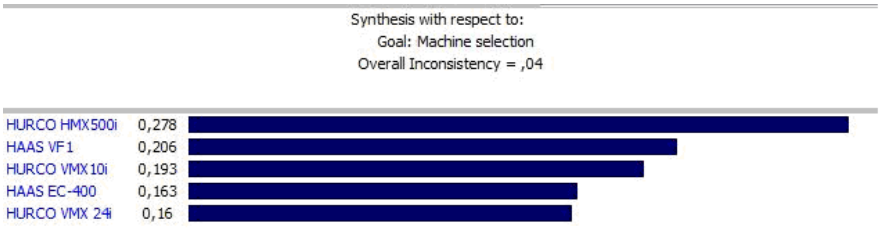

Figure 3 – Results for the big series

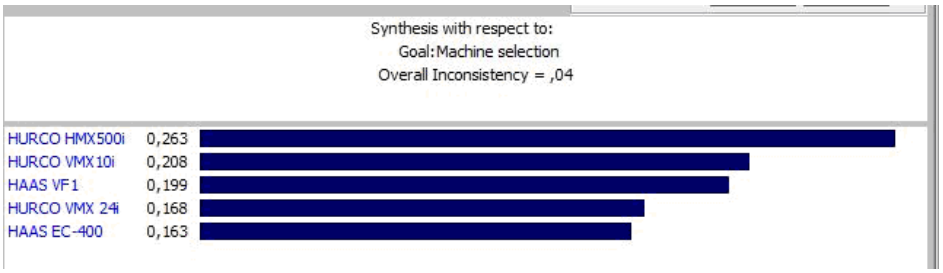

Figure 4 – Results for the small series

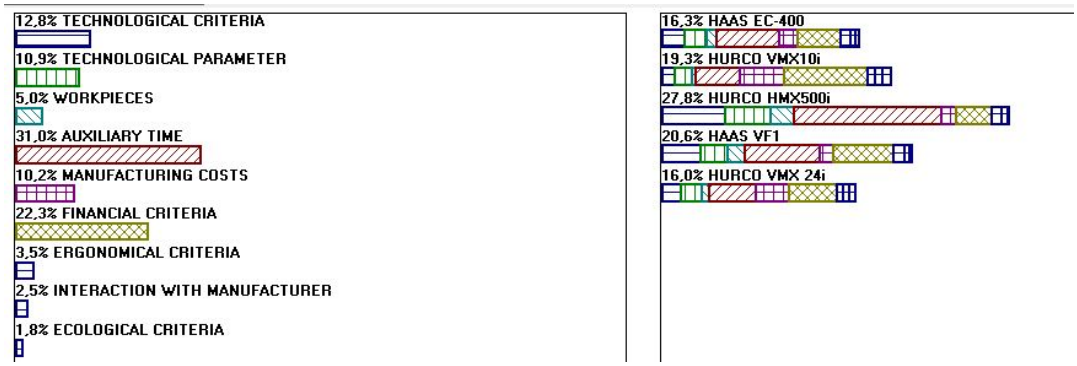

Figure 5 – Dynamic sensitivity graph for the big series production

This also leads to the question whether the alternatives are well chosen. The fact is that Hurco HMX 500i is a very powerful machine and has much better characteristics than other machines. This also depends on human subjectivity. The considered machines were chosen basically due their working space size. For the considered products, in theory, every machine centre can be chosen because the technological process does not have any special requirements. If the requirements are strict and special, there is a possibility to make a model so that certain alternatives would be eliminated automatically if they do not fulfil required specification.

Let us now observe what will happen if the Hurco HMX500i would be eliminated from the process. The results are shown in Figure 6.

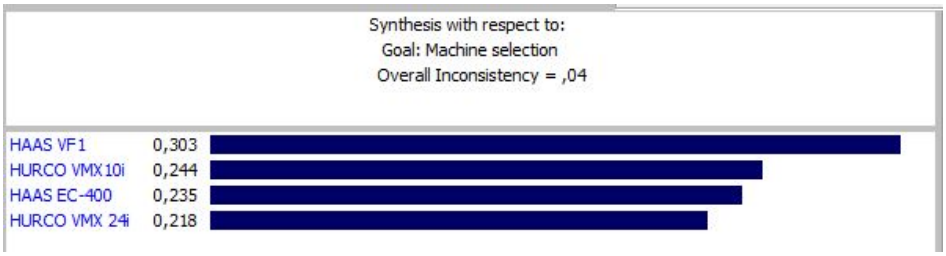

Figure 6 – Results for big series without Hurco HMX500i

Now HAAS VF1 is the best choice and other machines are rated just as in first case. Since VF1 was the first choice with the benefit/cost calculation and here it is the best choice without it, the conclusion can be made that additional benefit/cost calculation is not needed if the alternatives have similar characteristics.

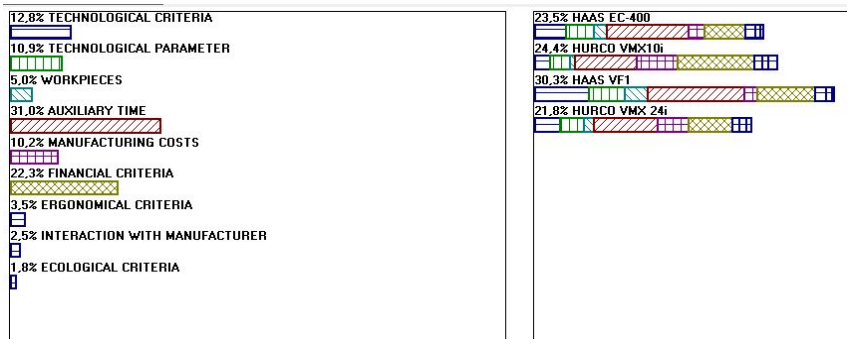

Figure 7 – Sensitivity graph without Hurco HMX500i

It is visible from Figure 7 that the importance of the criteria is the same, but the contribution of each criterion on the right has changed. Now the VF1 has the best auxiliary time criteria and VMX 10i has the best financial criteria. This is the situation where the AHP method is useful and helps in decision making process accurately.

In case when there are only five alternatives, results can mostly be kind-of expected. When the number of alternatives is small, the decision can be easily made by humans, because all the information is clear and can be easily compared. But when it comes to a big number of alternatives, then the situation gets pretty chaotic and decision should be supported with some kind of tool, in this case the AHP method will be used and explored [11].

5. RESULTS – EIGHTEEN ALTERNATIVES

When the number of alternatives increases, the problem arises at the very beginning. The first thing is different specifications available by various manufacturers, which requires digging deeper in order to get the needed information. Basic information available is the same, but there is a variation in specific information for the criteria structured in this way. The second problem concerns the qualitative criteria. Even if the machines are sorted and evaluated by their size of power, the pairwise comparison becomes very difficult and takes long time with high concentration required, which leads to the big possibility of mistake making. Also, this brings consistency in question because here with eighteen possible alternatives, it is very hard to be consistent and at the same time make a good and accurate model. What will happen if the number of alternatives increases to fifty or more? The AHP method is then a good choice, but only with different criteria structure. Since pairwise comparison becomes very complicated, the only solution is to make a model with quantitative criteria only. Then the work in Expert Choice would be much easier and the final results would be as accurate as possible. Since most of the information is not really available (like ecological, ergonomic or even technological criteria like preparatory time), this requires simpler criteria structure. In conclusion, using Expert Choice software isn't practical for more than eighteen alternatives if some criteria are qualitative so this scenario is held for future research and possible own-AHP software programming which would make this easier to deal with.

6. BENEFITS AND DISADVANTAGES OF USING AHP METHOD IN MACHINES SELECTION

There are many benefits of using the AHP method in decision making process, as well in machine tools selection. The fact that it is implemented in Expert Choice software makes it more useable in everyday situations and shortens the time of the process [4]. Expert Choice as a software itself is easy and user-friendly so there are no barriers while learning or using it [5]. Also, there is an option for group decision making [12].

On the other hand, there are many disadvantages of the method, primarily connected with the influence of human factor. People and their subjectivity are essential part of this method and in the end this can have effect on final decision, sometimes in a good, sometimes in a bad way. Some studies have shown that sometimes humans are more correct while using their own intuition [13], but it can also happen that this leads to wrong decisions. First the influence of the human factor is present in criteria structuring. They are usually structured and formed by brainstorming process of experts [14] which also has its disadvantages (some people may not express themselves and their knowledge while working in groups) [15]. This can be partly eliminated by using nominal group technique [16] in which people give ideas individually and evaluate them later anonyonimously. The next problem comes with criteria structuring. If the structure is uneven (different number of sub-criteria in various criteria) brings the question of the mathematical model and correct calculation of the influences of criteria in the final decision. It is advised to make a criteria-tree with equal number of sub-criteria in each criterion. Also, there are quantitative and qualitative criteria. The quantitative criteria are exact but the question is how to evaluate the qualitative criteria. One of the solutions can be their quantification. The link between the qualitative and the quantitative criteria should be considered. If there is one, it is possible to gather information, importance factors of connected criteria, multiply them (as "AND" operator in Boolean algebra [17]) and use the result as quantitative data for qualitative criteria.

Finally, another disadvantage is the number of criteria, which should not be bigger than ten, while using this method and software. Five criteria can be considered as some kind of optimum because of the possibility of controlling the process. With a bigger number of alternatives, the process gets really complicated and the user is unable to evaluate them. Future research can be therefore based on exploration of decision support method which can be adequate for this kind of situation.

With the mentioned solutions it is not possible to eliminate subjectivity in the AHP method and its disadvantages completely, but they can minimize it at some point. Also, the process of teamwork and its influence should be considered. [20] This can also be another way for the future research, each solution and its effect individually.

7. NEW MACHINES SELECTION TOOLS IN REAL PRODUCTION

The AHP method is still not used, or it is used very rarely in real life, in real production situations. It can be discussed what might be the reasons for this. That is why for this research one manufacturing company [12] and one manufacturing and machine sales company [13] were contacted to include their experience in new machines selection, the decision making process.

The process is very simple, mostly based on financial criteria, to be more accurate – the machine market price. The market price is divided by the number of working hours in the year. This gives new machine cost per hour. To this price additional manufacturing costs (i.e. energy, labour…) are added. Now there is a total cost of the machine per hour available. This cost is divided by the product price and the result is the number of products that should be produced in one hour to cover all the costs. If the machine cannot produce this number of products then it is excluded from further consideration. If it can, it can be considered. If the machine is more productive, which means that it can produce more products in one hour than required, this allows bigger income, faster depreciation period, or even decrease of the product market price. Depending on these three criteria, the manufacturer can decide the payment period – usually up to three years. This leads to the conclusion that sometimes more expensive and more powerful machines can be better, however, even the smaller and cheaper machines could seem as a better choice because of the market price.

Another practice in real production, when it comes to new machine tools selection, is individual decision making process where an expert with his knowledge about the offered alternatives decides which one to take. This approach is based on experience and the subjectivity factor has a big influence. Despite the knowledge, humans cannot evaluate more than three alternatives without any help [11]. This is moment when mistake occurs and have effect on company's future. To eliminate subjectivity of an individual, the solution seems to be in the teamwork [10] with the use of brainstorming process [7] and its variations, like nominal group brainstorming [14], which eliminates disadvantages of standard brainstorming process. Here a team of experts give ideas about the criteria and in the end discusses the final alternatives and they make a group decision with a higher accuracy than an individual decision maker [15]. So, in the future step of research we plan to develop a specific questionnaire to create attitude estimation of different experts' for machine tools selection.

8. CONCLUSION

Machines selection for future investment is a difficult decision making process for a company and may have many consequences for the future which can be more or less acceptable. Of course, every company leans towards positive consequences and bigger future income.

For making a better decision and for decision making process as objective as possible, a decision support systems can be used. The AHP method is one of the best options in these situations. The use is fast and simple, it is implemented in Expert Choice software which gives good results and is very user-friendly. However, this method has its limitations due to its characteristics. The human influence is really big, starting from the brainstorming process for criteria structure to the selection of alternatives and pairwise comparison. These are pretty subjective processes and have major influence on the final result at the same time. Also, there is no proper way to check whether the criteria are well chosen or structured. The only "control" is the consistency factor. This method is best to be used when all of the criteria are quantitative. Then the number of alternatives in the model does not have influence on the final result. In such case, the final decision is pretty accurate and based on the mathematical model that is proven and used.

This on the other hand requires much information that cannot always be given by the machine manufacturer or salesman. The problem is when the criteria are qualitative and pairwise comparison must be made. When the number of alternatives is relatively small (i.e. up to six alternatives) and they all have similar characteristics, the AHP method and Expert Choice software are a good choice. But when the number of alternative exceeds ten, the problem gets really complicated, mistakes can be easily made and results may not be accurate.

Future research can be directed towards own AHP software programming, which would make the evaluation of a higher number of alternatives simpler and easier for the user. Also, it would require bigger understanding of the algorithm and its possible improvement to eliminate some of its disadvantages. The second path of the future research will be focused on the problem of human subjectivity and its influence in decision making process when using the AHP model. The cognitive processes during decision making process and ways to make subjectivity less influential in the overall process will be explored. Qualitative criteria and their evaluation are related to the subjectivity problem so their quantification should be considered.

In cases with many alternatives some other software options should be considered, own databases or software made in programme language, which is left to be future course of the experiment.

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